

## **NUCLEIC ACID BASED FILTERS**

### **TECHNICAL FIELD**

This invention relates to the field of filters. More specifically, it is related to carcinogen-reducing filters formed from nucleic acids and more specifically filters for cigarette smoke.

BACKGROUND

Filters are generally used to remove an unwanted substance from a desirable substance. This may be accomplished by a variety of mechanisms, the two most prominent being size exclusion and adherence to the filter. Because most carcinogens are small  
5 molecules, adherence is the preferred method of carcinogen removal by a filter.

Previously a wide variety of filters have been constructed to remove carcinogens from other substances by inducing adherence of the carcinogens to the filter. However, these filters are often expensive, ineffective or dangerous or toxic themselves, among other problems. Applications for such filters abound and range from treatment of industrial  
10 effluents to removal of carcinogens, such as polycyclic aromatic hydrocarbons, from tobacco smoke. Accordingly, a need exists for additional carcinogen-binding filters.

SUMMARY OF THE INVENTION

The present invention includes a filter for carcinogen reduction. The filter may include a filtering surface operable to filter carcinogen-containing material and a carcinogen-reducing amount of nucleic acid.

5 In specific embodiments, the nucleic acid is distributed on the filtering surface. More specifically, the nucleic acid may be substantially uniformly distributed.

In other specific embodiments, the nucleic acid may provide structural support to the filter. In some filters the nucleic acid may comprise at least 80% of the filter by weight. In other filters, the nucleic acid may comprise 85%, 90%, 95% or even 99% of the filter by  
10 weight.

In specific embodiments, the nucleic acid comprises purified DNA or apurinic acid. More specifically, the nucleic acid may comprise 50%, 60%, 70%, 80% 90% or 95% DNA or apurinic acid, respectively by weight, volume or mol/total mol nucleic acid.

In certain embodiments the carcinogen-containing material may include a  
15 polyaromatic hydrocarbon. It may also include at least two carcinogens capable of reacting with nucleic acid.

In one specific embodiment, the filter is operable to filter carcinogen-containing tobacco smoke. In more specific embodiments, the filter may be of a shape and size to permit use as a cigarette filter, an air-intake filter for an air circulation system or a filter in a  
20 portable air filtration system.

In another specific embodiment, the filter is operable to filter carcinogen-containing combustion exhaust. In a more specific embodiment the exhaust is from an internal combustion engine and the filter is of a size and shape that permits use in an internal combustion exhaust system. In another more specific embodiment, the filter is of a size and  
25 shape that permits use in an industrial smoke stack.

In yet another specific embodiment, the filter is operable to filter carcinogen-containing liquid effluent and may be of a size and shape that permits use in a liquid effluent outlet pipe.

5 The invention also includes a method for reducing the amount of carcinogen in a carcinogen-containing material by passing the material through a filter of the present invention. In specific embodiments the carcinogen-containing material may include tobacco smoke, combustion exhaust and liquid effluent.

10 The invention includes a method of making a filter for carcinogen reduction by forming a filtering material into a porous filter body and applying a nucleic acid to the filtering material. In specific embodiments, the nucleic acid includes purified DNA or apurinic acid. In other specific embodiments, the nucleic acid may be applied in a liquid solution. The filter material may then be dried. After drying, a crosslinking agent may be applied to covalently bond the nucleic acid to the filtering material.

15 The invention additionally includes a method of making a filter for carcinogen reduction by purifying nucleic acid then forming the purified nucleic acid into a porous body. This may be accomplished, for example, by adding an aqueous nucleic acid solution to an alcohol solution in order to precipitate nucleic acid into a porous filter body. In specific embodiments, the nucleic acid includes purified DNA or apurinic acid. In other specific embodiments, the filter may also include other structural materials bonded to the DNA, such as small silica particles.

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BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference may be had to the following drawings and description of exemplary embodiments.

FIGURE 1 is a schematic drawing of a cigarette filter according to an embodiment of  
5 the present invention.

FIGURE 2 is a schematic drawing of an internal combustion engine exhaust filter according to an embodiment of the present invention.

FIGURE 3 is a schematic drawing of a smoke stack filter according to an embodiment of the present invention.

10 FIGURE 4 is a schematic drawing of a liquid effluent filter according to an embodiment of the present invention.

FIGURE 5 is a schematic drawing of an air circulation system filter according to an embodiment of the present invention.

15 FIGURE 6 is a schematic drawing of a portable air filter according to an embodiment of the present invention.

DETAILED DESCRIPTION

The present invention relates to a carcinogen filter containing nucleic acids. In a specific embodiment, it relates to a carcinogen filter containing DNA or apurinic acid. In some embodiments the filter may be made primarily from another material coated with nucleic acid or it may be formed from the nucleic acid. Such filters may be used to remove carcinogens from any material that may be passed through the filter. In specific embodiments they may be used to remove polyaromatic hydrocarbons from air or tobacco smoke.

Nucleic acids of the present invention may be any purified nucleic acid. They may be naturally occurring or artificially created. Nucleic acids specifically include apurinic acid, DNA (all forms, including cDNA) and RNA (including mRNA, tRNA and rRNA) as well as other nucleic acids.

The nucleic acid used in the present invention may be from any source. Harvesting techniques for recovery of nucleic acid from biological sources, including techniques capable of producing commercial volumes of nucleic acids are readily known in the art. Nucleic acids may be extracted from almost any biological source. Two common sources of non-specific nucleic acid are fish sperm and calf thymus. Almost any source, animal or plant-based, yeast or bacterial may be used. These sources may be specifically developed for nucleic acid harvest or may be waste products of other commercial processes, as in the case of calf thymus. Because the present invention employs nucleic acids for their chemical properties alone, and not for their information coding properties, the sequences of the nucleic acid may be irrelevant.

DNA, in certain examples, may be produced by solubilization of cellular material with a detergent, followed by extraction of nucleic acid from the aqueous layer with an alcohol. Various additional steps and additives may assist in the removal of protein to obtain purer nucleic acid. Various nucleases and extraction techniques may be employed to destroy unwanted forms of nucleic acids, such as RNA. Such techniques are well known in the art.

Nucleic acids may also be synthesized artificially from nucleotides. For instance, surface catalysis techniques or oligonucleotide synthesizers may be used.

The purity of nucleic acid from biological sources used in compositions of the present invention may vary by application. In most applications, the nucleic acid will contain no  
5 more than 50% by weight residual matter from the biological source such as proteins, lipids and carbohydrates. In certain embodiments, it will contain no more than 25%, 10%, 5% or 1% by weight residual matter. Such residual matter will likely include proteins, which may cause unwanted effects such as bad taste in cigarette filters or bacterial growth.

Nucleic acid is biodegradable and may also degrade due to damage from carcinogens,  
10 many of which are known to cause breaks in nucleic acid molecules. In many applications the rate of degradation of nucleic acid will not be significant. However, the rate may be influenced by the length of the nucleic acid molecule used and type of nucleic acid as well as by treatment of the nucleic acid.

The nucleic acid may also be crosslinked, although such crosslinking may reduce the  
15 carcinogen removal properties of the nucleic acid. Crosslinking may be between chains of a single DNA molecule or between chains of two different nucleic acid molecules or in any other possible permutation. Crosslinking may be accomplished in a variety of ways, including hydrogen bonds, ionic and covalent bonds,  $\pi\pi$  bonds, van der Waals forces. More specifically, crosslinking may be accomplished by UV radiation, esterification, hydrolysis, or  
20 silica compounds, siloxane bridges as described in U.S. Pat. No. 5,214,134, intercalating agents, neoplastic agents, formaldehyde and formalin.

More than one type of crosslinking may be used in a given composition. Furthermore, crosslinking may occur between two strands of a nucleic acid molecule or between two separate nucleic acid molecules.

25 Additionally, the nucleic acid may be methylated, ethylated, alkylated, or otherwise modified along the backbone to influence degradation rates. Generally, methylated, hemi-methylated, ethylated, or alkylated nucleic acids will degrade more slowly. Other backbone

modifications affecting degradation rates include the use of heteroatomic oligonucleoside carcinogen reduction capacity of nucleic acid.

Nucleic acids may also be capped to prevent degradation. Such caps are generally located at or near the termini of the nucleic acid chains. Examples of capping procedures are  
5 included in U.S. Pat. Nos. 5,245,022 and 5,567,810.

The size of the nucleic acid molecules used in filters of the present invention may vary from as small as 2 bases to as long as 10,000 bases or more. In general, most compositions will contain nucleic acid molecules with a variety of lengths. In exemplary embodiments, the average nucleic acid molecule length may be between 50 and 500 bases.

10 Apurinic acid may be obtained using any known processes, including the common process of hydrolysis of DNA in a strong acid to remove purines. Apurinic acid may be created before or after filter formation. It may also be treated in any suitable manner such as those described above with respect to nucleic acids.

15 The nucleic acid and the filtering material of the present invention may be provided as substantially pure chemical compounds free from contaminants or in less pure forms. If contaminants are present, it is preferred, especially in cigarette filters that the contaminants are not themselves hazardous or do not decompose to form hazardous compounds as the smoke passes through the filter.

20 Selection of the filtering material in different embodiments of the invention is pendent upon the end use of the filter. Likely candidates for the filtering material are paper, cotton, cellulose, cellulose acetate and glass fiber, with mixtures being possible. When the filter is used as a tobacco smoke filter, the filtering material conveniently is or includes cellulose acetate, the currently most common cigarette filter material.

25 Filters of the present invention may be formed by a variety of methods. In one method, an existing filter, such as a cellulosic cigarette filter, is coated with nucleic acid. Coating may be achieved in any suitable manner, including deposition from solution and spray or aerosol deposition. In another method, nucleic acid may be deposited on the filter



material before the filter is formed. In yet another method, the filter itself may use the nucleic acid as a structural element and may even be made primarily of nucleic acid.

In certain embodiments, the amount of nucleic acid that is used varies depending upon the size of the filter. It appears likely that nucleic acids remove carcinogens from materials by forming complexes with the carcinogens. Although it is also possible that nucleic acids may remove carcinogens by other methods, such as chemically altering the carcinogens, for selected embodiments of the present invention, it is assumed that complexes are formed. Accordingly, in such embodiments, it is assumed that the life of a filter will be relatively longer with an increased amount of nucleic acid present. Therefore, the amount of the nucleic acid used in the filter can be selected so as to substantially cover the surface of the filtering material. In more specific embodiments the amount of nucleic acid used in the filter covers at least about 5% of the surface of the filtering material. It may also cover at least about 10%, 15%, 20%, 30%, 40%, 50% or higher. In even more specific embodiments, the nucleic acid is substantially uniformly distributed on the surface of the filtering material. In other embodiments, the filter may be substantially formed from nucleic acid. More specifically, the filter may include at least 50%, 60%, 70%, 80%, 90%, 95% or even 99% nucleic acid by weight or filter material volume.

In one aspect of this embodiment, the filter is a cigarette filter including the filtering material and a nucleic acid free from hazardous contamination or any masking agent that may interfere with carcinogen removal. The nucleic acid is distributed on the surface of the filtering material. The amount of nucleic acid present is sufficient to substantially eliminate carcinogens capable of reacting with the nucleic acid from the tobacco smoke that passes through the filter. In a more specific embodiment, the nucleic acid is used in an amount that does not adversely affect the cigarette taste.

In another embodiment of the present invention, the filter is actually formed from nucleic acid as a structural material. The nucleic acid may be the primary structural material or may be combined with substantial amounts of other filter material.

Filters of the present invention may remove any carcinogen capable of reacting with the nucleic acid in the filter. Filters may differ in their efficiency of removal of different carcinogens. In selected embodiments, filter may be specifically tailored for removal of certain carcinogens, such as polyaromatic hydrocarbons from tobacco smoke, even if this results in less efficient removal of other carcinogens.

Filters of the present invention may be used to remove carcinogens from any source. The chemical makeup of the filter and the physical construction and shape may be adapted to facilitate removal of specific carcinogens or to accommodate a particular source. In specific examples the source is a gas or liquid. In more specific embodiments, the liquid may contain carcinogens in solution or in suspension.

In specific embodiments, the filters may be designed for removal of smoke from air. "Smoke" generally means the gaseous product of burning a carbonaceous material, usually made visible by the presence of small particles of carbon. Smoke containing carcinogens results, for example, from the pyrolysis of tobacco and the combustion of fuel by an internal combustion engine, particularly a diesel engine. Industrially, certain pyrolysis process smokes contain carcinogens.

In certain embodiments, DNA may serve as a good filter or filter coating for removal of polyaromatic hydrocarbons from tobacco smoke. In this embodiment of the filter of the present invention, the filter may be of a size and shape that permits use as a tobacco smoke filter. As a tobacco smoke filter, the filter is particularly useful as a cigarette filter, a filter in a cigarette or cigar holder, or a filter for a pipe.

In one embodiment of the present invention, shown in FIGURE 1, the filter is primarily for the filtration of tobacco smoke. In this embodiment, a filter 10 having a filtering material 12 is illustrated in use on a cigarette 14. The filter may have a conical cavity (not shown) or may have the configuration of a convention filter as depicted. The filter may be any type of filter of the present invention. In a more specific embodiment, it is a cellulosic filter coated with DNA or apurinic acid.

In a more specific embodiment, the filter contains a filtering material having a filtration surface area and airflow characteristics that in the normal untreated (no nucleic acid) state will provide removal of at least about 40-45% of the total particulate matter from the smoke passing through it. In an even more specific embodiment, the filtering material  
5 may have a filtration surface area and airflow characteristics that provide removal of at least about 50% of the total particulate matter from the smoke, or as much as 60-95% removal may be achieved in some embodiments.

In other specific embodiments, the nucleic acid may be substantially uniformly distributed on the surface of the filtering material. However, in other specific embodiments,  
10 where the airflow characteristics of the filter are such as to provide for ventilation of fresh air into the filter as a result of which the effective filtration surface area is reduced because of channeling of the smoke to certain areas of the filter, the nucleic acid may be substantially uniformly distributed over the effective filtration surface area of the filtering material.

Presently, in the manufacture of some commercial cigarette filters in the United  
15 States, ventilation of fresh diluting air into the filters is provided. As a result of fresh air ventilation, smoke is channeled through only a portion of the available filtration surface area. Thus, the effective filtration area in filters of this type is less than the available filtration surface area. Accordingly, the airflow characteristics of a filter may include fresh air ventilation. Other ways to affect the available filtration surface area by varying airflow  
20 characteristics are known in the filter making art. In general, filters of the present invention have recommended amounts of nucleic acid on surfaces over which smoke flows. The inclusion of nucleic acids on surfaces over which only fresh air or relatively smoke-free air flows is not as critical in certain embodiments of the present invention.

In a conventional fibrous tobacco smoke filter, the efficiency of the filter is related to  
25 the surface area of the fibers and the linear velocity of the smoke. For example, a typical fibrous filter with a surface area of 275 cm<sup>2</sup> has a pressure drop of about 2.8 inches and a filtration efficiency of about 46%. When the surface area of this conventional filter is increased substantially by adding more fibers, the pressure drop of the filter is increased

beyond the practical limit. For example, if the surface area of this filter is increased to about 500 cm<sup>2</sup> by adding more fibers, the efficiency of the filter is increased to about 66%, but the pressure drop is increased to about 7.5 inches. The filtration coefficient may be calculated from this data by the following equation:

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$$k = [-\ln(1-R)] \cdot \Delta P,$$

where R represents the filtration efficiency or percent of total particulate matter removed, and  $\Delta P$  is the pressure differential across the filter. The value of k for conventional filters  
10 made from textile tows is between 0.13 and 0.22 depending on the size and type of fibers (assuming  $\Delta P$  is expressed in inches of water at an airflow rate of 17.5 ml/sec.).

A conventional filter, having substantially uniform density from one end of the filter to the other, customarily used commercially in the United States has a filtration surface area and airflow characteristics that provide removal of about 40-45% of the total particulate  
15 matter from tobacco smoke. This type of filter generally has a total denier of at least 30,000, with an increase in surface area being provided by use of a relatively lower individual fiber denier, for a constant total denier. The filtering materials of the Marlboro® and Winston® filters are each believed to have a filtration surface area and airflow characteristics that provide removal of about 40-45% of the total particulate matter from tobacco smoke. In this  
20 regard, the Marlboro filter is believed to be characterized by about 36,000-42,000 total denier provided by individual fibers of about 3.6-4.2 denier, and characterized by about 5-15% fresh air ventilation.

Another type of filter used commercially in the U.S. is characterized by nonuniform density from one end of the filter to the other. One example of this type of filter has a  
25 conically-shaped cavity. Filters of this type are illustrated by U.S. Pat. No. 4,064,791 to Berger, the filter of which removes 60% or more of the total particulate matter. Other filters having a filtration surface area and airflow characteristics that provide removal of at least about 60%, and even up to about 95% of the total particulate matter from tobacco smoke are illustrated by U.S. Pat. Nos. 3,648,711, 3,599,646, and 3,533,416. The filtering material of

the Vantage® filter is believed to have a filtration surface area and airflow characteristics that provide removal of at least about 60% of the total particulate matter.

For purposes of the description contained herein, the percent of total particulate matter removed by the filtering material of the present invention is to be understood to exist  
5 when the pressure drop across the filter is about 2.0 to 2.5 inches of water, with up to 3 inches of water being contemplated. A pressure drop greater than about 3.0 is objectionable and not acceptable to the majority of cigarette smokers.

In a specific illustration of the embodiment of the present invention in which the filter is of a size and shape that permits use as a cigarette filter, the nucleic acid is DNA. The size  
10 of this cigarette filter is about 19 to 25 mm in length and about 7.8 mm in diameter. The amount of DNA in this filter is that amount provided by applying about 0.3 ml of an aqueous saturated DNA solution onto the filtering material of the cigarette filter. The aqueous solution is preferably applied by injection into the approximate midpoint of the filter. The amount of DNA distributed on the filtering material is about 5-7 mg.

In another embodiment of the present invention shown in FIGURES 2 and 3, a filter  
15 30 is used in conjunction with an exhaust system of an internal combustion engine or in conjunction with an industrial smoke stack. The filter comprises a filtering material, 32 with DNA or apurinic acid distributed on its surface. When the filter is used on an industrial smoke stack, a fan or ejector may be employed in order to provide an adequate smoke flow  
20 through the smoke stack. In FIGURE 2, filter 30 is shown in use on stack 34, and fan 36 is also shown. In FIGURE. 3, filter 30 is shown as part of an exhaust system 38 of an internal combustion engine 40. One suitable location of filter 30 in exhaust system 38 is shown in this figure. A location of the filter on the other side of muffler 42 is also possible.

In yet another embodiment of the present invention shown in FIGURE 4, a filter 50 is  
25 used in conjunction with a liquid effluent system. This liquid effluent system may be used in connection with an industrial process, such as paper processing, or as wastewater treatment, for example of water used to clean cement in gas station filling areas. Other processes in which carcinogens are introduced into a liquid effluent may also be used with the system of FIGURE 4. In the embodiment depicted, the filter 50 is located in an effluent outlet pipe 52,

which carries effluent 54 from a source 56 to a dump area 58. Additional treatment equipment 60 may also be connected to outlet pipe 52 for additional treatment of effluent 54, although such equipment is not required in all embodiments.

In the embodiment of the invention depicted in FIGURE 5, a filter 70 is part of an air circulation system. In the embodiment depicted, filter 70 is located near an air intake 72 and removed carcinogens before air reaches circulator 74. This embodiment may have the advantage of avoiding carcinogen build-up in circulator 74. However, in other embodiments the filter may be located at any point prior to air outlet 76. The embodiment of FIGURE 5 shows use of filter 70 in a home air circulation system. A similar system may be adapted for commercial settings. Although only one air intake is depicted in FIGURE 5, filters of the present invention are compatible with multiple intake systems. In multiple intake systems all filters in air intakes may be filters of the present invention, or filters of the present invention may be limited to air intakes in areas where carcinogens are likely to be introduced into the air, such as smoking areas or laboratory areas designed for airborne carcinogen use.

In the embodiment depicted in FIGURE 6, filter 80 is part of a portable air filtration system. Such system may be designed and used for home or commercial use. In specific embodiments, it is designed to regularly remove carcinogens from a small area. In other embodiments, it may be designed for emergency use, such as removal of carcinogens from a locality after a chemical spill or during warfare.

In the embodiments depicted in FIGURES 5 and 6, the filter may be prepared, in more specific embodiments, by coating a commercially available air filter otherwise suited for the appurtenant equipment with DNA or apurinic acid. Such coating may be achieved as described above in relation to cigarette filters. It is preferred that the coating not substantially reduce air flow through the filter and that the coating be in amount sufficient to substantially remove carcinogens from air passing through the filter when used as intended for the recommended filter life. For example, a filter designed to last for two months in a home smoking environment may be coated with a sufficient amount of nucleic acid to substantially remove the amount of carcinogens capable of removal by nucleic acids and expected to be in

the air of a stay-at-home smoker who smokes the national average number of cigarettes a day for at least two months.

5 All of the compositions and/or methods disclosed and claimed herein can be made and executed without undue experimentation in light of the present disclosure. While the filters and methods of this invention have been described in terms of specific embodiments, it will be apparent to those of skill in the art that variations may be applied to the filters and/or methods and in the steps or in the sequence of steps of the methods described herein without departing from the concept, spirit and scope of the invention. All such similar substitutes and  
10 modifications apparent to those skilled in the art are deemed to be within the spirit, scope and concept of the invention.